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LONG-RANGE FORECASTING AND OTHER WEATHER ILLUSIONS

BY J. PATTERSON

METEOROLOGY and Geology in their broader aspects treat of the two fundamental subjects that make life possible on the globe. While the soil may make life impossible in certain regions it is a fact that in most cases the necessary character of the soil to support life is almost entirely conditioned on the climate and it is chiefly the climate that determines the character of the life in any region. This then is a most important subject for investigation.

Meteorology as a science is very young, perhaps some would say that it has not yet arrived at the stage when it can be called an exact science, but it is progressing. As a branch of human knowledge, however, it is probably the oldest in the world, going back to the advent of man in the world. Primitive man was chiefly engaged in agriculture and hunting and as such would soon become familiar with the broader features of the climate, and as an observer of nature, he would be an observer of the weather, in order to protect himself against it or profit by it, rather than with any desire or thought as to the causes of the

various kinds of weather that he experienced. In course of time he soon acquired considerable local weather knowledge and this in turn became crystallized into proverbs which had all the finality of absoluteness about them. With the rise of the priestly caste, the weather was linked on to the constellations, and human and weather astrology went hand in hand. In fact, in Babylonian culture astro-meteorolgy formed part of their religion. This is the source of much of the popular weather wisdom that still survives, and it is applied independent of the locality to which it originally referred. Now belief in astrology in our country has practically died out as far as it refers to human beings, but it is not so in regard to weather astrology, all long-range forecasting that depends on the stars is simply astrology. It is one of the characteristics of human nature that the superstitions and weather proverbs learned in childhood survive through most of one's adult life. One other peculiar feature of human nature is the regard in which these so-called prophets are held. When they have attained a certain notoriety they are considered infallible, apparently because only the chance successful guesses are remembered and the rest are forgotten. The weather proverbs and much of the forecasting by stars arose in an age when all phenomena were a mystery and in many cases produced by a God of good or evil repute. That this nonsense should still survive is, no doubt, due to the fact that, to the great mass of the people, the weather phenomena are still a mystery. We are highly amused at the absurd stories of primitive people in regard to the creation, etc., but, considering their primitive character, should we consider these stories any more absurd than the weather proverbs and similar nonsense among people of the intelligence of those in our own country. It does point to this, that meteorology is almost entirely neglected throughout the whole of out educational system from the kindergaten to the university. This should not be so, but it is beyond my subject for this evening. I want you to look at this from another viewpoint.

It can best be illustrated by an example. Suppose you were

given the task of sprinkling an acre with water to the depth of one inch. How much work would you do. Suppose the source of the water was right at the centre of the field and that the field was circular of radius r feet. If you carried 6¼ gallons, or 1 cu. ft., each time, a simple calculation shows that you would have to travel nearly 110 miles to do it.

1 acre = 43,560 sq. ft.

r = 117·7 ft.

Average distance of travel = $\frac{2}{3}r \times 2$ = 156 ft.

No. of cu. ft. of water 43,560/12 = 3630

$$\text{Dist. travelled} = \frac{3630 \times 156}{5280} = 110 \text{ miles.}$$

By the time you had finished you would feel, in fact you would be absolutely certain, that you had performed a great deal of work; whether useful or not is another question. Now when nature starts her sprinkling can or turns on her hose, as she does at times, does she have to perform any work before she can do this or does she just do it without the expenditure of any energy? Let us see.

We all know that the moisture of the air is maintained by evaporation, and consequently all the moisture that is taken out of the air as rain was originally evaporated from the water on the earth's surface.

We also know that it requires heat to evaporate water, and experiment has shown that it requires as much heat to evaporate 1 lb. of water as it would require to heat 1080 lbs. one degree. That being so, we find that it would take to evaporate 3630 cu. ft. of water.

$$3630 \times \frac{125}{2} \times 1080 \text{ B. T. U.}$$

or expressed in work

$$= \frac{3630 \times 125 \times 1080 \times 778}{2 \quad 33000}$$

= 5,764,000 h.p. per min. = 96,000 h.p. per hour, or 4,000 h.p. per day.

This shows then that it would require a 96,000 h.p. engine working for one hour or a 4,000 h.p. engine for a whole day, transforming all its energy into the work of evaporation, to produce the vapor for one inch of rain on an acre. After the water has been evaporated it has to be raised to the level of the clouds about 4500 ft. or 1500 metres. The amount of work to do this is

$$\frac{3630 \times 125 \times 4500}{2 \times 33000} = 30{,}960 \text{ h.p. a min. or about } = 516 \text{ h.p.}$$

an hour or 21·5 h.p. per day.

The total amount of work required to get sufficient water to the level of the clouds to give one inch of rain on an acre is thus 5,764,000 + 30,960 or 5,794,960 h.p. That is truly a stupendous amount of work to give 1 inch of rain per acre, and now the question arises, can we find any source of energy that is capable of giving so much power year in and year out? In considering this problem, however, we do not need to consider an area of one acre but we can take 1 sq. cm. (·16 sq. in.) instead. Again let us take the precipitation for a year. In Toronto the average precipitation is about 34 in. per year and while 40 in. is much above the average precipitation for the whole year, we can for convenience consider an average precipitation of 40 in. or 100 cm. over the whole world.

A depth of 100 cm. of rain on a sq. cm. surface would give 100 grammes of water per sq. cm. The amount of heat required to evaporate this is 100 × 600 or 60,000 calories per year, or on an average 166⅔ calories per day but as the globe is made up of ¼ land and ¾ water and we consider the evaporation taking place from the water surface only, it would require 220 calories per sq. cm. per day of heat to evaporate sufficient water to give an average rainfall of 40 in. per year over the entire land and water surface of the globe. Where then can we find this amount of heat?

The Calendar Sunshine Recorder measures the amount of heat received on a horizontal surface from the sun, sky and cloud, and the following table gives the average amount per day and the maximum amount in one day for each month of the year.

At Toronto or on latitude 45° approximately, the daily average for the year is 256. The heat received per sq. cm. on a horizontal surface at latitude 45° would be approximately the

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.	Year
Maximum heat in one day per sq. cm. in gr. cal.	196	354	488	556	658	637	587	546	425	298	203	170	658
Average daily heat for the month. In gr. cal. per sq. in.	90	203	270	280	401	446	389	340	261	198	107	83	256
Evaporation total for month. In inches.	·65	·47	·95	1·44	3·14	4·09	3·29	2·81	1·96	1·28	1·10	·62	21·80

average for the globe per sq. cm. There is thus more than enough heat received from the sun to evaporate sufficient water to give an annual precipitation over the world of 40in.; the average precipitation is certainly much less than this. You see then that as far as evaporation is concerned the heat from the sun on the water surface is sufficient to evaporate all the water that is required for rainfall and still leave a considerable margin. Next, in regard to the energy required to lift the water to the level of the cloud or 1500 metres. To lift 1 gramme it will require an amount of energy equal to $1500 \times 100 \times 1000$ (approx.) $= 15 \times 10^7$ ergs, or expressed in heat units $= \frac{15 \times 10^7}{4{\cdot}2 \times 10^7} = 4$ calories approximately.

You know that when a gas is compressed, it is heated and that when it expands, it is cooled and that the cooling is independent of the time it takes to make the expansion provided there is no way of renewing the heat. We know that as we ascend, the pressure of the air gets less and so the vapor in rising is cooled and thus supplies at its own expense the energy required to lift it to the elevation. The energy required (4 calories) would be obtained by the air cooling 4°C. That is less than the average fall in temperature for that height. The vapor has next to be transported to the place where it is to be deposited, but as this is brought about by the pressure distribution of the atmos-

phere, it is not necessary for my purpose to consider it, nor what becomes of the heat that is given out by the vapor on condensing (this is equal to the heat required to evaporate the water) except to call your attention to the immense amount of power that is liberated for maintaining the energy of the cyclone or the agency that is producing the rainfall.

This shows then that it requires energy and a vast amount of it to produce rain, and that the only source that produces sufficient energy for the purpose is the sun. What I wish to emphasize strongly is this, that all the various phenomena which constitute our weather are not caused by mysterious or magical forces nor by the position of the stars, but they are produced solely by transformations of energy from one kind to another according to the known laws of physics. We cannot interpret all the phenomena of the weather yet largely because we do not fully know them. In astronomy you all know how many and varied were the motions devised to account for the true motions of the heavenly bodies, and while these held sway no progress was possible in regard to discovering the laws governing them; but when their true motion was discovered it was very soon followed by the correct theory, and the enunciation of the laws of gravitation.

Before it will be possible to formulate correct laws for weather phenomena, such as cyclones, etc., it will first of all be necessary to know the atmosphere, especially its circulation; then when this has been discovered, it may be possible to get the correct laws which govern the weather, and it will again be simply a matter of calculation to find out what the weather is going to be. The difficulties are, however, very great.

A word might be said here in regard to long-range forecasting attempted in some of the meteorological services throughout the world. These forecasts are based on meteorological conditions in different parts of the world for some months preceding the period to which the forecasts refer. In each year since the commencement of observations the conditions for these months are compared with the conditions that actually happened in the period

for which the forecast is made and by use of correlation co-efficients the probable conditions for the period are forecasted. The forecasts are thus empiricial and as only a comparatively few years' observations are obtainable, they cannot be said to have been very successful. Indeed, it is doubtful if long-range forecasting will ever be successful until the fundamental principles underlying the various meteorological phenomena are discovered.

For the rest of the time at my disposal, I propose to show how the recent developments in meteorology have changed the whole current of thought in regard to the weather. In other words most of the theories that were in vogue up to 15 or 20 years ago are now known to be illusions.

Meteorology as a science may be said to have had its origin about the middle of last century. In 1848, Piddington coined the word cyclone for one of the most pronounced features of the weather and described its principal features, and Galton introduced the word anti-cyclone in 1863. During the rest of last century meteorologists were engaged mainly in the study of cyclones and anti-cyclones. These studies were all made on observations at the surface, and necessarily so. It is true that Glaisher and others in the fifties and sixties of last century made many balloon ascents and while much information was obtained the results seemed confirmative of the ideas then prevalent. The ascents showed that temperature decreased with height, as was expected, for they believed that it fell off to the absolute zero of space. They also proved the existence of ascending and descending air currents, and that was in accordance with the theory of formation of certain kind of clouds. Observations were made on the form and motion of clouds and the cumulative result of all the conditions of the upper air as registered by surface instruments. From these facts meteorologists were obliged to form their theories of the origin of things meteorological, the origin of cyclones and anti-cyclones, how far up they extended and how they are formed. It was all speculation ; the atmosphere is a grand subject for speculation and the higher up you go the better for that purpose, since without observations it is very difficult to disprove the results

of the imagination and so we get into a region where hydrogen and geocoronium, an as yet undiscovered gas, form the chief constitutents of the air.

The constitution of dry air at the earth's surface is roughly 78 per cent. nitrogen, 21 per cent. oxygen, some carbon dioxide and traces of argon, hydrogen, neon, and helium ; water vapor forms about 1·2 per cent. of the atmosphere at the surface but decreases rapidly with height. At an elevation of about 75 miles calculation indicates that the hydrogen is practically the only gas present, or as some give it, the air is a mixture of hydrogen and geocoronium the density at that elevation bing ·0004. The variation of the density of the air with height is shown in Figure 1., where the density at the various heights is proportional to the width up to 50 km. (31 miles) ; above that height the density is so small that it cannot be represented by even the thickness of a line on that scale.

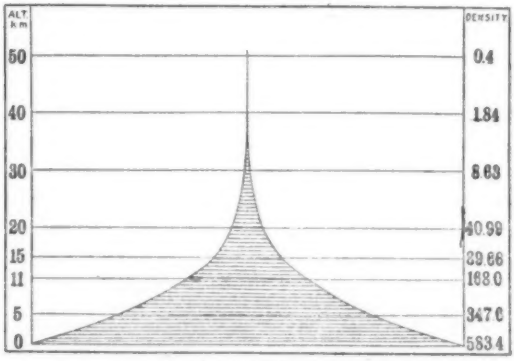
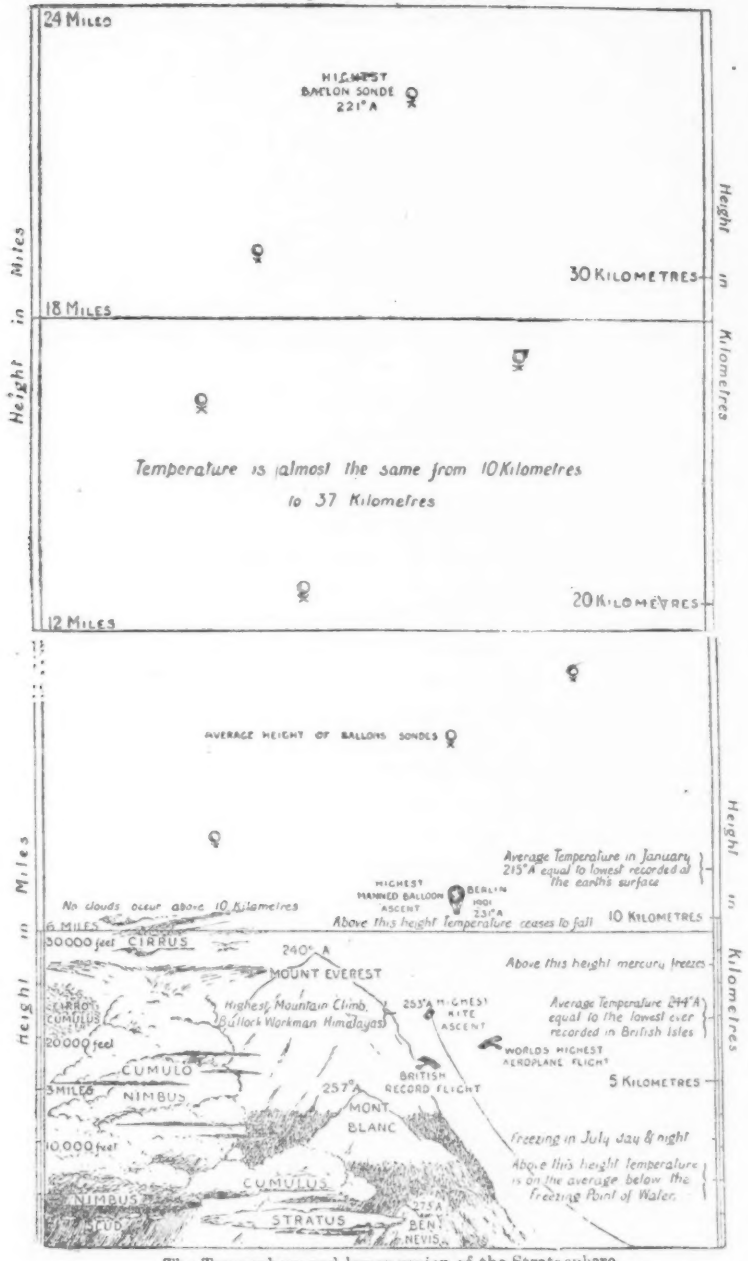


FIGURE 1.—W. J. Humphreys, "Physics of the Atmosphere," in *Journal of the Franklin Institute*, 1913

The principal sources of our information are shown in Figure 2.

The three chief methods of attack are by means of kites, balloons carrying instruments and those without instruments.

The Stratosphere from 12 to 24 miles.



The Troposphere and lower region of the Stratosphere.

FIGURE 2.—(From the Weather Map by Sir Napier Shaw.)

Kites give us information up to 2 or 3 km. Pilot balloons give the direction and velocity of the wind up to 10 or more kilometers and balloons with instruments have gone as high as 30 km. or more. This investigation has added an immense amount of information about our atmosphere and has shown that many of the theories that were extant when the work began were simply illusions due largely to the deceptive character of the surface observations, giving results that were applicable to the surface only.

One commonly accepted view was that as the air is heated from below, the change of temperature with height would soon disappear and you would get into a region where the temperature changes would be practically blotted out. The actual conditions are shown in Figure 3, based on results obtained in Toronto for a week of ascents in February, 1914. Here you see the temperature changes are just as great in magnitude at the higher elevations as at the surface. The former view is thus an illusion, the changes in temperature from day to day are just as great or greater at the height of 8 or 9 km. as they are at the surface, and moreover the change is approximately continuously throughout the atmosphere.

Again it was first believed that the temperature of the air decreased more or less continuously to the absolute zero of space, and perhaps the greatest advance meteorology made in many years was the shattering of this great illusion as shown in the diagram, Figure 4, taken from the observations obtained in Canada, together with the results found in other countries. You see from this that the temperature decreases continuously with height until about 10 km. or so is reached, after which there is either no change or an increase. This region is known as the stratosphere in distinction from the lower region the troposphere. The troposphere is the region of convection while the stratosphere is the region of no convection or the region in which convection has ceased. The stratosphere is highest and coldest at the equator and appears to be lowest and warmest at the poles. In equatorial regions, the height is about 17 to 18 km. (11 miles)

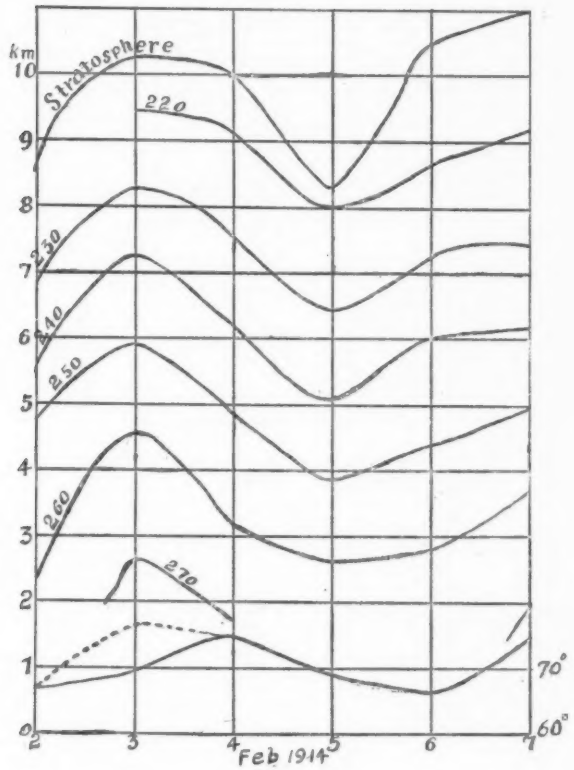


FIGURE 3

VERTICAL TEMPERATURE CHANGES FOR FEBRUARY, 1914

and the average lowest temperature – 75°C (– 103°F.) or less, the lowest yet recorded being – 91°C (– 130°F.). In the latitude of Toronto the height is about 12 km. (7½ miles) and its mean temperature – 61°C (– 77°F.).

Galton stated in 1863 that most meteorologists are agreed that a circumscribed area of barometric depression is usually a locus of light ascending currents and, therefore, of an indraught of surface winds which create a retrograde whirl (in our atmos-

phere) consequently we ought to admit that a similar area of barometric elevation is usually a locus of dense descending currents and, therefore, of a dispersion of a cold dry atmosphere, plunging from the higher region upon the surface of the earth, which flowing away radially on all sides becomes at length imbued with a lateral motion due to the above mentioned cause, though acting in a different manner and in opposite directions. The

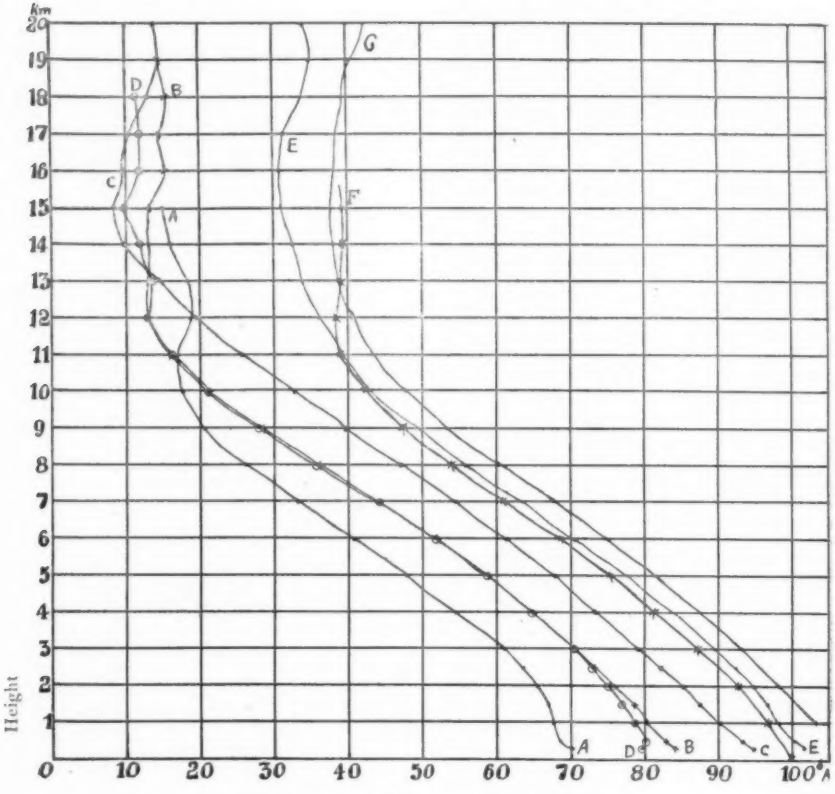


FIGURE 4 — TEMPERATURE (ABS.)

The curves are :—A = Winter ; B = Spring ; C = Summer ; D = Autumn ; E = Year increased 20° ; F = Year increased 20° for Europe ; and G = Year increased 20° for United States.

weather map for 8 a.m. March 7th, 1917, illustrates this description very well. (Fig. 5).

Taking the above definition of a cyclone and an anti-cyclone,

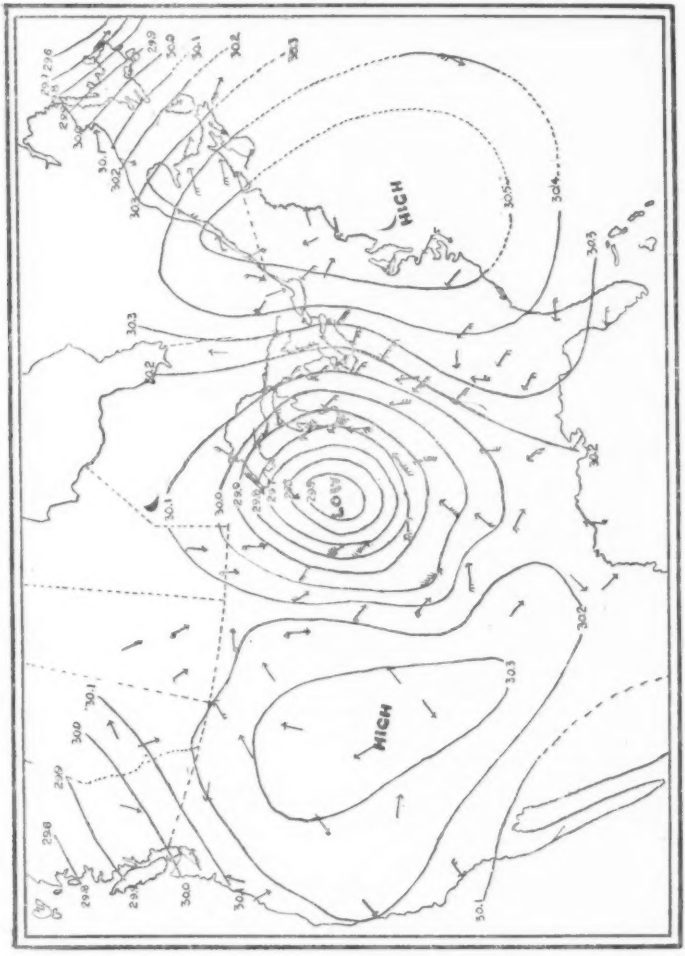


FIGURE 5 — WEATHER MAP, MARCH 7, 1917

both of which give a very accurate description of the cyclone and anti-cyclone as they are represented on the map, we notice that there are three distinct parts.

1. Convection. 2. Convergence. 3. Circulation : counter clockwise in the cyclone and clockwise in in the anti-cyclone.

A careful examination of the statement shows that it is really the convection that supplies the driving force for the whole process. We can also see from the chart the natural sequence of events as they appear from the surface observations. We look on convection as the ascent of warm currents in a relatively cold environment, thus giving low pressure on account of the relative by high temperature, and, consequently, the descent of cold currents in a relatively warm environment would give high pressure. The convergence across the isobars is due to the low pressure and the circulation is the deviation from the straight path produced by the rotation of the earth.

This is a very simple and elegant theory, for it ascribes the origin of cyclones to convection and this is, perhaps, best elaborated by Ferrel, who said that in consequence of the differences in density due to differences in temperature in a horizontal direction a convectional interchange of air between the areas of different temperatures arises and there result differences in pressure and consequently cyclones. This theory then assigns the cause of cyclones to convection and the convection of warmed air currents has always been regarded as the cause of winds. It has been the accepted cause of Monsoon and Trade winds and taking it as the cause also of cyclones, we have a very simple unity in meteorological theory. The origin of all winds is thereby assigned directly to what appears to be their ultimate cause, namely, the warming of the lower layers of air by the warmed surface of sea and land. Let us now see how these views will stand the test of observation in the upper air.

Notice that the driving force in all these motions is the ascending air of the cyclone no matter the extent of country concerned. Observations show that the convective region is about 10 km. high, a distance that would be represented by 1

inch when 1000 miles equals about 15 ft. The cyclone then cannot be considered as a sort of top heavy towering structure such as we think tornadoes and waterspouts to be, only on a much vaster scale.

Again consider the spiral motion around the isobars in a cyclone or low (Fig. 5); from this it appears that there is a flow of air into the central area or, in other words, that all the air circulating about the low pressure is finally drawn into the centre where it ascends, but Shaw and Lemphert have shown in their paper on the "Life History of Surface Air Currents" that there is a mistake here, for owing to the movement of cyclones the winds, by aiming at the centre, miss their aim and land in a region of higher pressure. In other words, if they had wanted to reach the centre they should not have aimed at it. This is shown in Figure 6 taken from the paper on the subject. There is, of course, convection in the centre of the low pressure area but it is local and not general for the whole cyclone.

In the weather map (Fig. 5), we see very plainly the convergence of the wind across the isobars but as we ascend in the atmosphere the observations show that this convergence decreases, and at about 1500 feet above the surface there is very little evidence of any convergence across the isobars; the general opinion is that at that level or near it, convergence has ceased to exist and the motion is then along the isobars and the velocity of the wind is given by $\frac{\lambda}{\rho} = 2\omega V \sin\theta \pm \frac{v^2}{r}$, where λ is the pressure gradiant, ρ the density of the air, ω the angular rotation of the earth, V the velocity of the wind, θ the latitude of the place and r the radius of the small circle in which the air moves.

The velocity may be obtained approximately by the formula $V = 3900/M$ or $3300/M$ for lat. 40° and 50° respectively, where V is the velocity in miles per hour and M is the distance between the isobars in statute miles, the isobars being drawn for every 0·1 in. What really happens at the surface is this. The friction of the surface converts part of the motion into eddy motion and it does

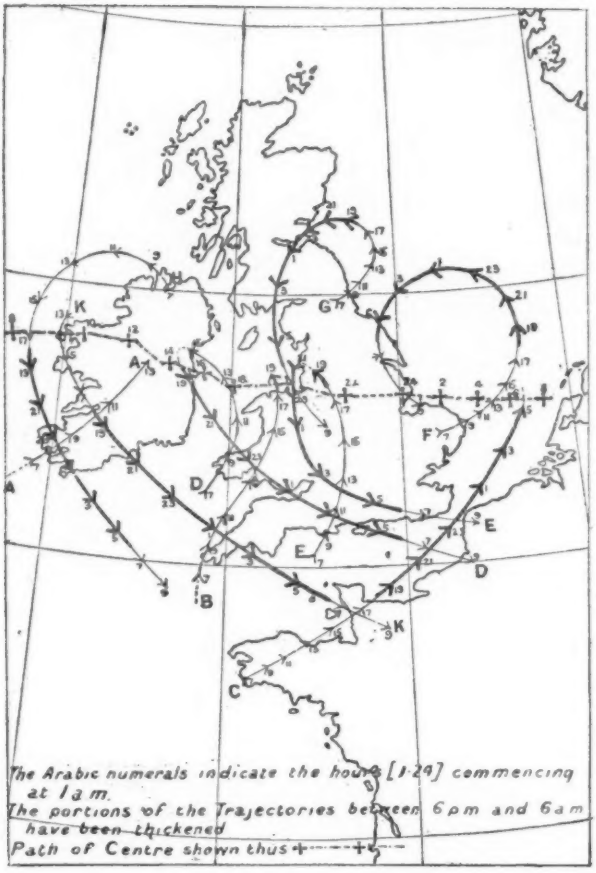

The Arabic numerals indicate the hours [1-24] commencing at 1 a.m.
The portions of the Trajectories between 6 p.m and 6 a.m have been thickened
Path of Centre shown thus +---+---

FIGURE 6

not now move fast enough on the right path to keep up the motion and consequently drifts inward, but as the viscosity of the air is very slight the lower layers cannot hold back the upper layers very far above them, and so as soon as this region is passed the true motions of the wind with reference to the isobar is

obtained. That is along the isobars. The convergence then is an illusion.

As already stated the theory of the cyclone requires that the air of the cyclone should be warmer than that of the anti-cyclone and Arrhenius, of Stockholm, in 1903 gave a picture, Fig. 7, of the action of cyclones and anti-cyclones.

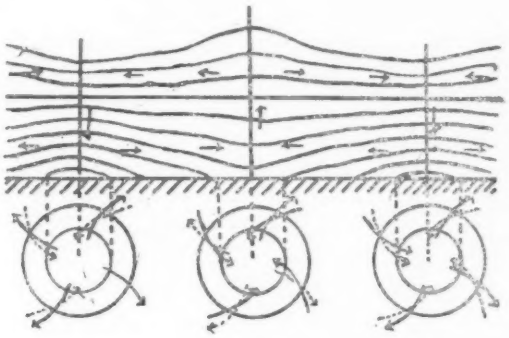


FIGURE 7.

ARRHENIUS PICTURE OF CYCLONES AND ANTI-CYCLONES

Briefly, the centre of a low or cyclone is warm and the air that blows spirally about the low ascends, as shown in the figure, and as it ascends it cools until a neutral surface is reached, above which the air over the cyclonic area is colder than the surrounding and flows outward as indicated by the arrow. On the other hand the anti-cyclone is a region of high pressure and low temperature up to the neutral plane, above which the reverse is true in regard to the surrounding air, and there is thus a downward flow of air over the anti-cyclone which is gradually converted into a horizontal motion. The observations in the upper air, however, show the actual conditions as given in the adjoining table. Low pressure means pressure below 740 mm. at M.S.L., high pressure is for pressure above 770 mm. This table and Fig. 8 were prepared by W. H. Dines from the observations made in Britain.

CONDITIONS IN THE UPPER AIR

Height		Pressure		Temperature		Pressure		Temperature	
Mls.	Km.	High mb	Low mb	High °A	Low °A	High in.	Low in.	High °F	Low °F
6·21	10	273	247	226	225	8·07	7·30	- 53	- 54
5·59	9	317	288	233	226	9·37	8·50	- 40	- 53
4·97	8	366	335	240	227	10·81	9·90	- 27	- 51
4·35	7	422	388	247	232	12·47	11·46	- 15	- 42
3·73	6	483	449	254	240	14·27	13·26	- 2	- 27
3·11	5	552	516	261	248	16·30	15·23	10	- 13
2·49	4	628	591	267	255	18·55	17·45	21	0
1·86	3	713	675	272	263	21·06	19·93	30	14
1·24	2	807	767	277	269	23·83	22·64	39	25
0·62	1	913	870	279	275	26·96	25·69	43	36
0	0	1031	984	282	279	30·45	29·06	48	43

Pressure is expressed in millibars, 1000 mb. = 750 mm. = 29″·53.

In temperature expressed on the absolute scale, freezing point = 273° and boiling point 373°.

Britain is well situated for showing this phenomenon as very many of the central areas of the weather systems pass over the country. Here in Ontario, very few of them do. But notice what this table shows. The temperature in the low pressure area is colder throughout than that in the high pressure.

At the 10 km. level, the pressure difference between the high and low is 26 mbs. (1000 mbs. = 750 mm.), that is at the level where convection has ceased, but at the surface this difference is increased to 47 mbs. by the existence of the high pressure transmitted from above in spite of the relative coldness of the air at the low pressure. These results are shown in Figure 8. While the table gives the conditions below the 10 km. level, the figure shows that there is a remarkable change above that level, and the conditions are now reversed, the high is colder than the low. This is caused by the fall of temperature in the high continuing to a greater height than in the low and it thus becomes colder; in other words, the stratosphere is higher over a high than over a low. Meteorologists are thus being forced to the conclusion that the differences of cyclones and anti-cyclones are

not surface effects at all but that their origin must be sought in the upper atmosphere and they are surmising that the origin is at the boundary between the troposphere and the stratosphere,

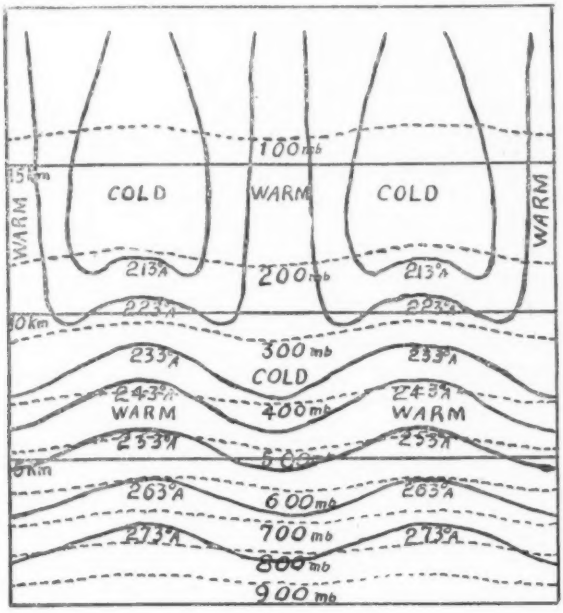


FIGURE 8

ACTUAL CONDITIONS IN CYCLONES AND ANTI-CYCLONES

the boundary of the region where convection ceases. According to this view they are little affected by the lower stratum of 9 km. which roughly marks the limit of the effect of heating at the earth's surface. The idea of the warm air in a cyclone is seen to be an illusion. Thus it would appear that the essential parts of the simple and elegant theory used to explain cyclones and anti-cylones are illusory. What they took for their guidance was the accidental character of the motion near the ground.

It used to be considered and, perhaps, is yet by many, that

as moist air is lighter bulk for bulk than dry air, the moist air is the cause of the low pressure and a low barometer is indicative of rain. This is not true to facts, for on examining the upper air data it is found that there is no connection between moist air and a low barometer : it is an illusion.

One other point may be mentioned here. So far it has been found impossible to predict the exact movement or development of a cyclonic disturbance from the surface observations. I feel that if the disturbance was of surface origin and depended on surface conditions for its development and propagation, meteorologists would have discovered these facts by this time. As however, they have been unable to do so, it would imply that they have not been looking in the right place for them.

I shall not pursue the subject further to-night because I would have to go again in to the realm of speculation which most probably would be only another illusion, although no one would know it until it was revealed by observations. But I think enough has been said to show you the great importance of the upper air investigation to the proper understanding of our weather. As I said in the beginning, we cannot hope to solve the problem of the weather until we know our atmosphere. Already the investigation has shown how erroneous were our views on weather phenomena, when only surface observations were available. It is clear that a knowledge of these conditions alone would never in this world have enabled us to properly interpret weather phenomena ; on the other hand a full investigation of the atmosphere does hold out the hope that we may be able to discover the laws underlying the weather.

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TORONTO, ONT.

TWO GREAT PROBLEMS OF THE UNIVERSE*

By W. W. Campbell

I. Evidence of Matter in Space Obstructing the Passage of Light

OUR photographic telescopes are confirming William Herschel's observation that these large and formless nebulæ are in or are bordered by regions of sky showing fewer stars than abound in the surrounding regions. The bright stars in the Pleiades, those really belonging to the cluster, are numerous, but within the cluster as we see it, and in a considerable area of the adjacent sky, the faint stars are markedly scarcer than in the areas farther away. Barnard has found that the sky in the region around the Pleiades group is possessed of much nebulosity. It is a natural question, are the faint stars scarce because the nebulosity there existing has not yet condensed into stellar forms? This may be true in part, but we shall find much more probable the view that the faint stars are deficient in numbers because the nebular materials, at a certain distance away from us, are obstructing the light of the faint stars that are farther away from us than the nebula is. A similar deficiency of faint stars exists within the great nebula of Orion, and likewise in the adjacent areas, where Mr. William H. Pickering has found a very large part of the constellation of Orion to be covered with faint nebulosity. There are so many regions in and near the galaxy where these relationships exist (that is, a presence of nebulosity and a scarcity of faint stars) that we can not doubt their significance. The faint stars are relatively scarce chiefly

*Portions of the presidential address to the American Association for the Advancement of Science, New York City, December 26, 1916. The title of the address was "The Nebulæ" and it was published in full, with numerous illustrations, in *Science* for May 25, 1917.

because the nebular materials cut off the light of the more distant stars. This explanation is reached by several lines of evidence, but we take time to present only one.

It is established by modern astronomy that the individual stars are in rapid motion. The speeds of the naked-eye stars average about sixteen miles per second. The distant fainter stars, so far as they have been observed, are also travelling rapidly. There is a tendency to favor certain directions of motion, and the stars in certain small groups are keeping company through space; but a large share of stellar motion is at random. There are stars travelling in all directions. We have not the direct evidence as to the motions of the faint stars in the far distant outposts of the galaxy, but we have no reason to suspect that their characteristic motions are unique. We can see no escape from the condition that all the stars are in motion. Under these circumstances we are unable to explain how within a great volume of space that is rich in stars there can be a smaller, but still enormous volume of space, nearly free of stars. Their random motions should distribute them more uniformly than we observe to be the case. Let us illustrate by the celebrated black holes, the so-called "coal sacks," in the constellation of Sagittarius. In a region where the stars are especially plentiful are two small areas all but empty of visible stars. How can such great "holes" through the stellar system be surrounded by a plenitude of stars moving more or less at random so as to give a high density of star distribution right up to the sharply defined edges of the holes, and yet leave the holes empty of stars? With the help of all astronomical experience we can not explain the phenomena by the absence of stars. I think we must assume, with Barnard and others, that the stars are actually there, and that they are invisible because invisible materials between us and the stars are absorbing or occulting the light which the stars are trying to send us. Much of the interesting structure in the Milky Way is probably due in a like manner to obstruction by materials lying between us and the great clouds of stars. It is characteristic of the galactic structure that where luminous nebulæ seem to re-

duce the numbers of faint stars visible, the reduction in numbers of stars extends also far out beyond the limits of visible nebulosity, and we can scarcely resist the conclusion that invisible extensions of the luminous nebular fabric exist as obstructing agents.

There are many other lines of evidence in support of the hypothesis that invisible matter exists in abundance within the stellar system :

1. Newcomb and Kelvin, working independently and on the assumption that the motions of the stars are generated by gravitational attractions originating within the stellar system, were unable to account for the high observed velocities of stars, except on the hypothesis that the visible stars contain only a small fraction of the matter existing in the system ; the greater part of the attracting material in the stellar system being non-luminous, or at least invisible.

2. There must be an enormous amount of comet material distributed throughout space. The astronomers discover only a negligibly small proportion of the comets which pass near the center of our solar system. May not comet materials exist also in abundance in the systems of the other stars?

3. Students of meteors have established that the separate little bodies which collide with the earth's atmosphere and are responsible for the so-called shooting stars are stupendous in numbers. It has been estimated that as many as twenty or thirty millions of such bodies collide with the earth every twenty-four hours. How incomparably and inconceivably greater must be the total number in our solar system. The power of these countless particles to obstruct the passage of light is not negligible. There may be as many such particles on the average around the other stars in our stellar system.

4. The so-called new stars, otherwise known as temporary stars, afford interesting evidence on this point. These are stars which suddenly flash out at points where previously no stars were known to exist ; or, in a few cases, where a faint existing star has in a few days become immensely brighter. Twenty-nine

such stars have been observed in the past three centuries, nineteen of them since 1886 when the photographic dry plate was applied systematically to the mapping of the heavens, and fifteen of the nineteen are to the credit of the Harvard observers. This is an average of one new star in less than two years in the last three decades; and, as some of the fainter new stars undoubtedly come and go unseen, it is evident that they are by no means rare objects. Now all of the temporary stars except five appeared in the Milky Way, and four of the five exceptions are worthy of note. Two of the five appeared in well-known nebulæ; another was located close to the edge of a spiral nebula, and quite probably in a faint outlying part of it; a fourth was observed to have a nebulous halo about it; and the fifth was but meagerly and imperfectly observed. Keeping the story as short as possible, a temporary star is seemingly best explained on the theory that a dark or relatively dark star travelling rapidly through space has met with resistance, such as a great nebula or cloud of particles would afford. While passing through the cloud the star is in effect bombarded at high velocity by the resisting materials. The surface strata become heated, and the luminosity of the star increases rapidly. The new star of February, 1901, in Perseus afforded interesting testimony. Wolf, at Heidelberg, photographed in August an irregular nebulous object near the star. Ritchey's photograph of September showed extensive areas of nebulosity in all directions from the star. In October Perrine and Ritchey discovered that the nebular structure had apparently moved outward from the star. Going back to a March photograph, taken for a different purpose, Perrine found recorded upon it an irregular ring of nebulosity closely surrounding the star which was not visible on later photographs. The region seemed to be full of nebulosity not visible to us under normal conditions. The rushing of the dark star into and through this resisting medium made the star the brightest one in the northern sky for several days. The great wave of light going out from the star when at this maximum brightness travelled far enough in five weeks to fall upon non-luminous materials and made a

ring of nebulosity visible by reflection. Continuing its progress, with a speed of 186,000 miles per second, the wave of light illuminated the material which Wolf photographed far away from the star in August, the material which Ritchey photographed still farther away in September, and the still more distant materials which Perrine and Ritchey photographed in October, November and in later months. We were able to see this material only as the very strong wave of light which left the star at maximum brightness made the material luminous in passing.

We can scarcely doubt, in view of all these facts, that there is a stupendous amount of obstructing material scattered throughout our stellar system. This may eventually be condensed into stars; but the point I wish to emphasize is that the material is there, and is evidently obstructing the passage of light. The efficiency of the obstructing material is, no doubt, the greater in the long dimensions of the system; in the direction of the Milky Way.

II. The Order of Evolution of the Stars

While a strong case can be made out for the evolution of planetary nebulæ into stars at their centres, with possible planets revolving around them, we must not conclude that all stars have been formed from planetary nebulæ. There are reasons for rejecting that view.

1. Amongst the many millions of stars whose images have been examined in the telescopes or on photographic plates, fewer than 150 planetary nebulæ have been found. Unless the planetary-nebula stage of existence is lived very rapidly, the numbers are too few to play a controlling part in the development of stars in general at any point in stellar evolution.

2. The average speeds of the planetary nebulæ and of the different classes of stars are now fairly well defined. The average speed of the planetary nebulæ is about seven times that of the extremely blue stars, which are the only ones, we shall see later, that we need consider as the immediate descendants of the nebulæ. There are, indeed, individual stars which are travelling

as rapidly as the individual planetary nebulæ, but on the average the discrepancy seems entirely too great to let us conclude that the blue stars in general could have been formed from planetary nebulæ such as the 150 planetaries now known to us.

For the hypothesis that the stars in general have evolved from irregular nebulæ a vastly stronger case can be made.

In a priceless possession of astronomy, the Draper catalogue of stellar spectra, Harvard College Observatory has classified the spectra of a great many thousands of the brighter stars. They have been arranged in a sequence, runniug from the so-called extremely blue stars through the yellow stars to the red stars, which can be readily described. Each main class has ten sub-divisions, but we need not dwell upon details. The dark lines in these spectra indicate the presence of certain vapors and gases of the chemical elements in the outer strata of the stars. In the Class *B* stars the helium lines rise to their maximum strength near the middle of the *B* sub-groups and sink to insignificance in the later *B* or earlier *A* sub-divisions, and the helium lines are not found at all in Class *F* and the later types. The hydrogen lines are fairly prominent in the Class *B* stars, but they increase to maximum intensity in Class *A*, and then decrease continuously throughout the remaining groups. The hydrogen lines are very inconspicuous in Class *M*, or red stars. The magnesium lines go up to a maximum in Class *A* and down to disappearance in the *F*'s and *G*'s. Some of the metallic lines, such as titanium and iron, usually begin to show in the later sub-divisions of Class *A*, other metallic lines first enter upon the scene in Class *F*, and they increase in numbers and prominence up to a maximum in the red stars. The calcium lines are weak or entirely wanting in the Class *B*'s, and they increase in intensity as we pass down through the series, until they become the most prominent features in the spectra. We can not change the arrangement of these spectral classes without throwing the sequence of development of the spectral lines into hopeless disorder. This sequence is thought to represent the order of stellar evolution. A Class *B* star according to

that hypothesis, is a comparatively young star. It should develop, in the course of long ages, into an *F*, a *G*, a *K*, an *M*, and so on, to its final destination of darkness and invisibillty.

Some of the Class *B* stars contain bright lines of hydrogen. Alcyone and Pleione, in the Pleiades, contain both bright and dark lines of hydrogen. There are hundreds of stars whose spectra contain a wide variety of bright lines and dark lines. Now and then a star's spectrum consists almost wholly of bright lines, as in the case of Eta Carinæ. The bright lines in stellar spectra tell us that their stars contain extremely extensive atmospheres of the gases and vapors hydrogen, helium, and so on. A close relationship exists between the Class *B* stars, with and without bright lines, and a class of stars found extensively in the Milky Way structure whose spectra, containing many bright lines, are known as Wolf-Rayet spectra, after the discoverers of the first few stars in the class. Now, as Wright has shown, the central stars in the planetary nebulæ are of the Wolf-Rayet type in nearly all cases, and in other cases their spectra are closely related to Class *B* spectra. It has been shown, also chiefly by Wright, that the spectra of the nebulous parts of the planetary nebulæ have many points of connection with the spectra of their central stars. The spectra of the planetary nebulæ and the spectra of those large extended nebulæ which give bright lines are essentially alike in character. The nebulium lines of the nebulæ have never been found to exist in any true star, no matter what its class, and we leave them out of account in this discussion ; they do not influence our present question one way or the other. Aside from nebulium, the hydrogen and helium lines are the most prominent ones in the bright-line nebulæ. They are the most prominent ones in the nuclei of the planetary nebulæ. They are prominent in the isolated Wolf-Rayet stars, in the Class *B* stars containing bright lines, and in the Class *B* stars containing only dark lines. Helium has never been found in any yellow or red stars, except feebly in a certain stratum of our sun's atmosphere, and that is due to our ability to observe

our sun somewhat in detail; and the hydrogen is relatively feeble in the later classes of the Harvard sequence.

The continuous spectra of stars as arranged in the Harvard sequence decrease continuously in the relative strength of the blue, violet and ultra-violet regions as we pass from the central stars of the planetary nebulæ, which are wonderfully strong in ultra-violet light, down through the blue stars with both bright and dark lines, through the blue stars containing dark lines only, and on through the yellow stars to the red stars. The central star in the ring nebula in Lyra is invisible to many inexperienced observers, even in the great Lick telescope. Yet it is so rich in violet light, and especially in ultra-violet light, that it can be photographed in the great reflecting telescopes with an exposure of only two or three seconds. Wright has recently made the interesting discovery that the continuous spectra of many planetary nebulæ are remarkably strong in a long stretch of the ultra violet region. The sequence of decreasing richness in blue and violet light extends unbroken from the nebulæ and nebular nuclei down to the red stars.

The spectra of the stars are indicative of conditions existing in their surface strata. We do not know definitely just what conditions produce or accompany certain types of spectra, but surface temperature seems to be a prime influence, and there are some reasons for thinking that electrical conditions may also be extremely important. Now all determinations of the surface temperatures of the stars make the extreme blue-violet stars the hottest of all, with the effective temperatures decreasing continuously as we pass from the nuclear stars of the planetary nebulæ down through the Harvard sequence to the red stars. Fabry and his associates in Marseilles have recently arrived at the result, by physical methods, that the temperature of the Orion nebula is very high, vastly higher than the temperatures of the red and yellow stars, and comparable with the temperatures of the blue stars. There again is a sequence with the nebulæ and the blue stars at one end and the red stars at the other.

Fowler has called attention to the remarkable facts that cer-

tain lines of helium, etc., requiring the most powerful electric discharges at command to produce them in the laboratory—super-spark lines, he calls them—are found in the greatest relative strength in the gaseous nebulæ; next in order of strength in the bright-line or Wolf-Rayet stars, which class includes the central stars of the planetary nebulæ; and in lesser strength in the first sub-division of the Class *B* stars, that is, in the bluest of the blue stars containing dark lines only; secondly, that the lines in the spectra of the later Class *B* stars, of the Class *A* and Class *F* stars are prevailingly those produced under the less intense conditions of the ordinary electric spark; and, thirdly, that the lines in the yellow-red stars are prevailing the arc lines which indicate relatively weak electrical conditions. That is another sequence of conditions running from the nebulæ down to the red stars.

There are still other sequences running harmoniously through the Harvard classification. For example, the velocities of the stars in their travels within the stellar system increase as we pass by spectral classes from the large bright-line nebulæ and the very blue stars down through the yellow stars to the red stars. The distances apart of the two components of double stars, and consequently their periods of revolution around each other, increase consecutively as we pass from the blue stars to the red.

It might be said that, so far as all these stellar sequences are concerned, the course of evolution could begin with either the red stars or the blue stars and proceed to the other end of the sequence. Not to mention several very weighty objections to the assumption that the red stars are effectively young and the blue stars effectively old, we submit the case on the evidence of the nebulæ. The planetary nebulæ, the irregular nebulæ, the Wolf-Rayet stars, the Class *B* stars with bright lines, and the Class *B* stars with dark lines are found prevailingly in and near the galaxy.

The Class *B* stars and the stars containing bright lines are where the planetary and irregular nebulæ exist. Going further

into detail: whereever there is a great nebulous region either in, or near, or outside of the Milky Way you will find the Class *B* and earlier types of stars abnormally plentiful; and the chances are fairly strong that some of the stellar spectra will contain bright lines. This is true of great regions in the Milky Way, it is true of the Orion and Pleiades regions, which we see at some distance outside of the Milky Way structure, though they are doubtless within our system. If you find a red or yellow star of normal type, do not look for a nebula in apparent contact with it. Nebulæ and red stars do not co-exist. You will find about the same number of red stars in the Milky Way that are visible in similar areas far from the Milky Way. You will find an occasional red star in the region of the Orion nebula and of other large nebulæ, but red stars will not appear there in greater numbers than their approximately uniform distribution over the sky requires.

The connection between the nebulæ and the bright-line stars, and between the nebulæ and the early Class *B* stars is close, both as to their types of spectra and as to their geometric distribution.

Do the nebulæ form stars or do the stars form nebulæ, or both? There is abundant evidence that the catastrophes which produce new or temporary stars produce temporary nebulæ, for at a certain stage of their existence the temporary stars have nebular spectra; but in all cases thus far observed — as Adams has shown — the nebular spectrum quickly transforms itself into the Wolf-Rayet stellar spectrum It is not impossible that the planetary nebulæ have in some cases resulted from the more violent catastrophes of distant space and time; that bodies originally stars may have been expanded under the heat of collision or other catastrophe to nebular conditions; but that an ultimate condensation will transform such nebulæ again into the stellar state, we can not doubt. That such nebulæ as those in the Pleiades or as the great Net-Work nebula in Cygnus were formed from stars can not be regarded with favor for a moment; but that the many Class *B* stars existing in those regions should have been formed

from nebulous matter, and that others may be forming, implies an evolutionary process that is both natural and easy of comprehension. Transformation from star to nebula is abnormal, is *rev*olution, under the influence of catastrophe. Transformation from nebula to star is normal, is *ev*olution; under the continuous and regular operation of the simple laws of physics.

Those who would suggest that the red stars may be the young stars must start with stars uniformly distributed over the sky, and unassociated with nebulosity; and, transforming them through and past the red and yellow stages, must carry them prevailingly into the galactic regions, where, as Class *B*, or extremely blue stars, they preferentially collect in the great nebulous areas, or, in many cases, become enmeshed in details of nebulous structure. We should pause long and consider well before embarking upon a voyage in that direction.

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THE RAINBOW

By Otto Klotz

PERHAPS some elementary statements about the rainbow may be of interest to some of the readers of the JOURNAL. Theoretically no two persons see the same rainbow. The rainbow is a color sensation, and has as little substance as the colors flashed from a diamond. The position and height in the heavens of the rainbow is a matter of relative position of the sun, the observer and the minute drops of water in the air in which the rays of the sun are twice refracted and once reflected, as seen in the accompanying figure (Fig. 1). When a ray of white sun-light

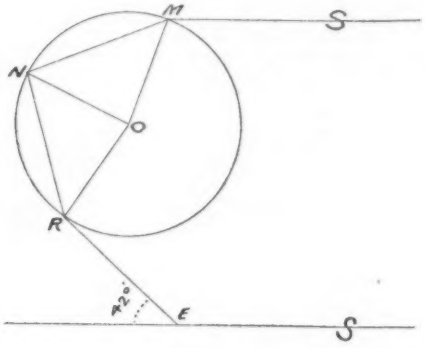

FIGURE 1

strikes the globule it is refracted, and as rays of different wave-lengths have different indices of refraction, the white ray, which is simply a bundle of many rays of different wave-lengths, is broken up into its constituent parts, and some of these when they reach the eye produce the sensation of color. For simplicity, of what is intended to be conveyed, we shall confine ourselves to a single ray of the bundle, say the ray that gives us the sensation of red. The ray $S\ M$ (Fig. 1) strikes the globule at

M, here it is refracted at a certain and definite angle with the radius *O M* to *N*. Here part of it passes out of the globule and is lost to us while another part is reflected again with a definite angle *O N R* equal to *O N M*. At *R* it emerges from the drop and is again refracted into the air, suffering the same refraction as when it entered, and reaches the eye at *E*. Now every one of the myriads of globules of water that are in the air when a rainbow is seen, sends out such refracted rays and one would imagine a blaze of color as the result, but, of course, such can not be the case for, as we have seen, if we follow any particular ray, one that is to reach the eye after it has been twice refracted and once reflected, we shall find that it must have a definite position in the sky with reference to the observer and the sun. The ray that we are considering makes an angle of 42° with the line joining the observer and the sun. The distance that the globule is away from the observer is immaterial, as every one knows when he sees a rainbow when using a lawn sprinkler. It is the angle spoken of above that is the governing factor. Now having this angle fixed in our mind, it readily follows that every globule situated at this angle will give us a ray of this particular color (red). Hence we see an arc in the heavens and which is the base of a cone having its apex at the eye and making an angle of 42° with the axis. This gives the fundamental idea of the rainbow, for any time of the day and for any position of the sun. On account of the distance of the sun, we may consider all its rays parallel, and parallel to the line, observer—sun. To still further impress this fundamental, imagine a rod to connect the sun with the observer and let it be produced and serve as an axis, *C E S* (Fig. 2); at the eye imagine a cone to project *R E P* (Fig. 2), with its surface making an angle of 42° with the axis *C E S*. We have hence a rigid system which serves us for all rainbows, and this rigid system is movable at the position of the eye, one end of the axis pointing to the sun. As the sun goes down the rainbow goes up, *i. e.*, the visible arc is increased until at sun-rise or sun-set we have a semi-circle, the greatest arc possible on the prairie; as the sun goes up the arc goes down,

so that when the sun reaches an altitude of 42° the rainbow disappears on the horizon. There can be no rainbow at or about noon in our latitude during the summer months. If we had taken another ray with a different index of refraction the reasoning would have been just the same, but the angle of our cone

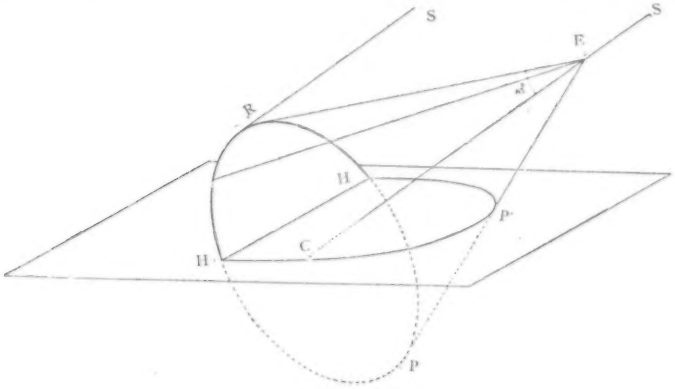

FIGURE 2

would be a little different. For violet, which is at the other end of the spectrum, the angle would have been 40°, *i. e.*, at a less altitude, and hence we find violet at the inside of the bow. Some years ago in an address, I gave as a simple mnemonic to remember the order of the colors in the rainbow, for I find that few people know it, although they have seen rainbows scores of times, the word I V O R, signifying "inside violet, outside red."

When viewing a rainbow one always has his back to the sun, and each observer is in the line of the centre or middle of the bow seen. No two persons see exactly the same bow. When a second rainbow is seen above the brighter one, it is due to two reflections within the globule, in consequence of which the order of the colors is reversed, *i. e.*, the red now forms the inside band and the violet the outside one.

So much for the rainbow in the sky; but at times there are seen "ground-bows." These are seen in fields covered with

gossamer of spider webs and dew, as many will recall having seen especially on fallow fields and commons. In *Nature* of March 2, 1916, Mr. A. E. Heath describes very well by word and diagrams one seen by him. The form of the bow on the ground follows immediately by applying the above rigid system of cone and axis. We find that the form must be a conic section — the intersection of the cone with the ground — and, hence, may be a circle, an ellipse, a parabola or a hyperbola. To give a circle about one's feet the sun would have to be directly overhead, *i. e.*, in the zenith, and the circle would have a radius of about 5 feet, assuming the eye at 5½ feet above the ground. As the sun declined from the zenith the form would change to an ellipse becoming more and more elongated until at an altitude of 42° the intersection would be parallel to an element of the cone and hence a parabola ; and from 42° to 0° altitude, the form would be a hyperbola, the figure seen and measured by Mr. Heath. These ground-bows are probably mostly seen in the early morning hours before the dew has evaporated, yet are not restricted in time as is the rainbow, which has a limit for the altitude of the sun. A phenomenon which, as far as known to the writer, has never been seen, is a rainbow and a ground-bow at the same time. It certainly would be a pretty sight. From one's feet the arms of the hyperbola — for a hyperbola it would be — would run along the ground and meet the feet of the arc of the rainbow spanning the sky, as shown diagramatically in Figure 2.

In Figure 2, $H\,R\,H$ represents a rainbow with the sun at altitude of 30°. $H\,H$ represents the horizon and $R\,H\,P\,H$ the circular base of the cone. $H\,P'\,H$ is the intersection of the cone by the ground and hence represents the ground-bow when the ground is covered with water globules.

In conclusion reference may be made to a somewhat rare phenomenon of a ground-bow seen at night due to the same law of refraction and reflection but where the source of light is an electric street lamp and the ground covered with minute drops of water. In the case referred to by Dr. C. G. Knott, in the *Pro-*

ceedings of the Royal Society of Edinburgh, in December, 1898, the minute spheres of water were due to the settling of fog in quiescent air. Here we have not parallel rays, as with the sun, and the form of the bow is not that of a conic section. From the adjoining Figure 3 we readily deduce the equation of the curve of this ground-bow. L is the position of the light, E that of the eye, and P any point on the curve on the the horizontal ground. O is the origin, and the measurements are as indicated.

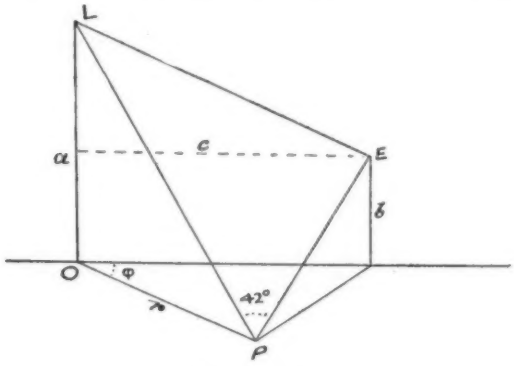

FIGURE 3

Expressing this in terms of the measurements we obtain

$$(r^2 - r\,c\cos\phi + a\,b)^2 =$$
$$\cos^2 42^\circ\,(r^2 + a^2)\,(b^2 + r^2 + c^2 - 2\,r\,c\cos\phi),$$

an equation of the fourth degree. When the eye is directly under the light the equation becomes that of a circle, and in general r will have two values, *i. e.*, there will be two circular ground-bows.

The question of horizontal bows has recently been treated by Kokichi Otobe, in the U. S. *Monthly Weather Review* for April, 1917.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
June 14, 1917.

A PHENOMENON AND ITS EXPLANATION

By E. A. Hodgson

THE photograph which accompanies this article shows a rather curious phenomenon which appeared on a photographic record during a series of experiments with the instrument for recording the deformation of the earth under the influence of the moon.

It offers such a good illustration of the need of checking every possible factor in an endeavor to explain a given result, that it may be of interest to readers of the Journal.

The arrangement of the experiment so far as this result is

concerned was as follows:—A relay was put on in place of one of the mean time seconds dials of the observatory in such a way that each second it flashed for a brief instant an ordinary incandescent lamp running on the alternating city current. This lamp furnished the source of light which, brought to a point of light by an optical system, fell upon a sheet of photographic paper moving slowly at the rate of 17 mm. per hour. During the last minute of each hour the light was eclipsed by a shutter. This accounts for the regular breaks about 12 mm. apart on the reduced section of the record shown here. It will be noted that this section is nine hours long. The whole record was 22 hours long and of the same nature throughout.

The variation in intensity of the line had no bearing on the experiment and was not expected, but an attempt was made to explain it. It was found that if the tension of the relay was relaxed so that it closed for a longer time each second the effect disappeared. This led to the following explanation. Suppose the relay flashes the light while the current passes through two bright phases and a dark or dimmer intervening period. If the current be 60 cycle exactly there will be 120 such bright phases per second. If, however, it be slightly more or less than an even number of cycles per second the relay, which closed at exactly the same time each second, would soon cease to show two bright phases and a dark phase, and it would come after a time to show two darks and a bright and the record would dim. In order that this might be the result, the relay would need to close very briefly each time, for if it closed for, say, ten bright and nine dark phases and then after a time crept on to ten dark and nine bright ones the contrast would not be noticeable. And it was found, as has been mentioned, that the phenomenon failed to appear if the relay was relaxed so as to close for a longer period each time.

This explanation was not quite satisfactory in that it is doubtful whether the incandescent lamp really darkens while the current is off as is the case in an arc lamp, and it was still less probable that the power house was able to maintain the current at precisely the same number of cycles per second for a period of 22 hours as was necessary in order that the record should be as regular as it was for that time.

Mr. R. M. Stewart became interested in the record and finally gave the correct interpretation which was as follows :— It was noted that there were just 79 dark positions in 16 hours. This is half the number of coincidences of beat of the sidereal and mean time dials. The sidereal and mean time dials are on the same battery here and the arrangement is such that at one coincidence all the dials draw from the same half of the battery and at the next coincidence the sidereal and the mean time dials draw from opposite halves. When both sets draw from the same half each dial receives slightly less current than when they draw

from opposite halves, and hence the relay which took the place of one of the mean time dials received less current at each alternate coincidence and as it was drawn up tightly it closed very briefly and the lamp was flashed for a shorter instant at each second coincidence and the record became dimmed 79 times in 16 hours. It will be noted that the effect disappears if the relay be relaxed, which was required also by the other explanation and was the greatest fact in its favor when the real cause was unknown.

DOMINION OBSERVATORY,
OTTAWA, CANADA.
May 31st, 1917

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

June, 1917

Temperature.—The temperature was below the average throughout the Dom nion, except at Chatham, N.B.; Charlottetown, P.E.I., and on the Island of Anticosti, where it was a little above. The chief negative departures were 7° at Elora, 6° at Parry Sound and Huntsville, 5° at Port Arthur, 4° at Vancouver, Barkerville, Minnedosa, Port Stanley and Toronto, and 3° at Kamloops, Qu'Appelle, Winnipeg, Ottawa and Montreal.

Precipitation.—The rainfall was very much below the average over the Western Provinces, except in a few isolated places, notably Qu'Appelle and The Pas. It was also below the average over the Lake Superior district, and north of and including the Ottawa Valley, also locally in Prince Edward Island, and in Eastern Nova Scotia. Elsewhere in the Dominion it was nearly everywhere greatly above the average, the excess being very pronounced in the Interior of British Columbia, the Peninsula of Ontario and in Quebec and New Brunswick.

July, 1917

Temperature.—The mean temperature along the coast-line of British Columbia and in the Barkerville district was from 3° to 6° below normal, while in the southern interior portion of the Province it varied from normal near the coast to 3° above in

eastern districts. In the Prairie Provinces the normal was exceeded by from 3° to 6°. In Ontario the very cool weather of the former part of the month was more than counter-balanced by the great warmth of the latter part, in the northern portion, but this was not generally the case in the southern portion. In Quebec and northern New Brunswick mean temperatures ranged from normal to 3° above, while in the remainder of the Maritime Provinces they ranged from average to 3° below.

Precipitation.—In Southern British Columbia, Southern Alberta, Saskatchewan and Western Manitoba the rainfall was light, amounting generally to less than one inch. In Ontario the normal precipitation was well exceeded, except in the region between Kingston and Haliburton, and in the district of Thunder Bay. From the Ottawa River to the Atlantic Ocean there were frequent showers during the month, but although the normal rainfall was largely exceeded in Western Quebec, it was not, except locally, reached in the region from the Saguenay River to Cape Breton Island.

Temperature for June and July, 1917

Station	June		July	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	76	25	78	32
British Columbia				
Atlin	73	29	69	32
Agassiz	42	28	87	38
Barkerville	70	27	76	32
Kamloops	89	42	98	46
New Westminster	82	39	83	40
Prince Rupert	72	30	68	44
Vancouver	77	41	83	47
Victoria	78	43	81	49
Western Provinces				
Battleford	85	37	94	40
Calgary	88	32	91	34
Edmonton	80	33	86	40
Medicine Hat	91	37	101	46
Minnedosa	93	28	98	32
Moose Jaw	89	32	105	37
Oakbank	89	25	87	42
Portage la Prairie	95	33		
Prince Albert	82	29	96	42
Qu'Appelle	81	31	102	34
Regina	86	31	104	34
Saskatoon	85	31	92	40
Souris	97	29	95	37
Swift Current	86	33	100	40
Winnipeg	94	27	92	42
Ontario				
Agincourt	81	36	97	45
Aurora	82	35	92	44
Bancroft	82	34	95	43
Barrie	83	38	93	48
Beatrice	81	31	89	45
Bloomfield	77	42	89	47
Chapleau	82		94	21
Chatham	86	42	100	50
Clinton	84	36	92	44
Collingwood				
Cottam	88	43		
Georgetown	83	39	94	49
Goderich			90	40
Grimsby	85	41		
Guelph	81	37	94	45
Haliburton	87	32	95	40
Huntsville	84	35	93	39
Kenora	85	30	89	43
Kinmount	84	32	93	41
Kingston	79	43	88	51
Kitchener	82	42	96	46
London	85	38	98	46
Lucknow	80	34	91	40
Markdale	83	36	94	42
North Gower	85	33		
Oshawa	80	36		
Ottawa	84	34	97	51
Paris	95	39	98	47
Parry Sound	84	40	92	44
Peterboro'	82	39	95	45
Port Arthur	78	34	89	44
Port Dover	78	42	94	48
Port Stanley	76	40	90	47
Queensborough	80	36	94	42
Ronville	81	34	90	45
Southampton	82	40	95	45
Stonecliffe	90	40	94	52
Stony Creek	84	43	96	49
Toronto	83	41	98	49
Uxbridge	82	37	94	45
Wallaceburg	83	40	96	48
Welland	85	41		
White River	85	24	91	31
Quebec				
Brome	84	40	92	42
Father Point	72	36	76	46
Montreal	82	49	92	52
Quebec	79	43	88	51
Sherbrooke	84	42	90	42
Maritime Provinces				
Charlottetown	78		86	52
Chatham	86		94	50
Dalhousie				
Fredericton	80	37	92	45
Halifax	80	34	86	48
Moncton	85	38	87	46
St. John	73	40	86	48
Sussex	78	34	86	44
Sydney	82	34	88	43
Yarmouth	70	36	80	48

Earthquake Records by the Milne Seismograph

TORONTO

Sir Frederic Stupart, Director.

P.T. = Preliminary Tremors. S. = Secondary Waves. L.W. = Large Waves. A.C. = Air Currents. Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1917	P. T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks
		h m	h m	h m	h m	h m	mm	
1718	June 3	19 48·8?		19 59·7	20 04·2	20 17·1	0·3	
1719	" 4	1 36·6?	1 44·9	1 57·1	2 01·8	3 41·5?	1·9	6,790 km.
1720	" 4			8 30·1	8 31·6	8 35·1	0·2	
1721	" 6			5 01·5	5 08·8	5 35·0	0·2	
1722	" 6	16 35·5?	16 43·1	16 54·2	16 56·8	17 09·8	0·2	
1723	" 7			3 14·6	3 19·0	3 32·0	0·4	
1724	" 8		1 03·0	1 06·0 } 1 07·0 }	1 09·8	4 04·6	8·7	P. not recorded. [3,792 km.* L-S
1725	" 9			18 03·0	18 05·0		0·7	(*a*)
1726	" 10		4 45·3	4 52·0	4 54·6	5 39·8	1·8	
1727	" 13	7 00·7?	7 11·2	7 42·0	7 48·3	10 30·3	4·8	(*b*) 9,400 km. de-
1728	" 16			16 08·7		16 23·9	0·05	[fined disturb'ce.
1729	" 16			16 35·1		16 52·1	0·05	
1730	" 22			5 59·0	6 00·4	6 18·9	0·2	
1731	" 24	20 07·3?	20 13·8	20 16·7	20 18·2	22 17·2	0·3	4,780 km. S. well [defined.
1732	" 26	6 04·3.	6 15·0	6 32·4 } 6 42·0 }	6 51·1	10 51·6	20?	(*c*) 9650 km.
1733	" 27			12 04·3? } 12 26·2 }				
1734	" 27	12 39·4	12 43·4	12 46·4	12 48·4	13 47·6	1·4	
1735	" 28			14 48·3 } 15 06·9 }			0·4?	Some phases lost [attend'g instru.
1736	" 29		16 19·4	16 26·0	16 26·7	17 13·0	0·4	P. not recorded
1737	" 30		18 01·6 } 18 02·0 }	18 09·5	18 11·5	19 16·4	0·8	(*d*) S. doubtful.
1738	July 1	13 27·8?	13 34·7?	13 38·8	13 39·1	13 53·2	0·2	(*e*)
1739	" 4		1 04·5	1 12·1 } 1 25·2 }	1 38·3	2 44·2	0·4	Distant quake
1740	" 4	6 29·4		6 39·8	6 54·0	7 14·5	0·2	Dist. quake. P.
1741	" 9			0 17·8 } 0 55·5 }			0·05	[phase may be [the S waves.
1742	" 11			23 34·6	23 43·0	24 05·5	0·3	(*f*)
1743	" 12			12 46·1	12 56·5	13 19·1	0·3	
1744	" 12			13 57·9		14 06·3	0·05	
1745	" 13	5 27·5?		5 30·4?	5 35·3	5 42·4	0·05	
	" 15	Earthq	uake lost,	clock stop	ped.			
1746	" 25	3 24·2	3 35·7	3 47·1	3 51·6	5 18·6	1·8	
1747	" 25	22 42·7	22 52·9?	23 01·7	23 04·4	23 31·4?	0·3	
1748	" 27	1 06·9	1 11·6	1 13·4	1 21·1		9·3	2,990 km. F. [merged into an- [other quake.
1749	" 27	3 01·7?	3 13·2	3 25·5	3 48·0	5 36·2	0·8	(*g*) 10740 km.
1750	" 27	16 20·4	16 26·0	16 28·4	16 28·8	17 14·2	0·3	3,810 km.

TORONTO.—(*Continued*)

No.	Date 1917	P. T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks
		h m	h m	h m	h m	h m	mm.	
1751	" 28			0 40·1) 0 47·9)		1 06·5	0·05	
1752	" 28			1 44·4	1 45·7	1 57·8	0·2	
1753	" 29	14 51·9) 14 55·9)	15 08·6	15 21 8	15 28·6	16 53·3	1·6	Possibly 2 quakes overlapping.
1754	" 29	22 11·7?	22 23 6	22 35·6	23 08·8	A. C.	4·3	Repeat 23h 56·0m or another quake
1755	" 30			17 31·0) 17 35·6)			0·05	
1756	" 31	0 21·1	0 29·0?	0 41·2	0 58·2	A. C.	0·9	Strong micros going on.
1757	" 31	3 25·2?	3 34 0	3 45·8	3 46·0	A. C.	0·4	7,380 km.?

Period of boom 18 seconds. Pillar inclination 1mm. = 0".50.

* Repeat 3h 17·9m. Press say "San Salvador destroyed."

(*a*) Paper off at first phases. F. lost when paper payed out irregularly.

(*b*) Well marked at Max. 3 Maximum. Repeat 8h 57·2m also 9h 56·2m.

(*c*) Duration 4h 47·3m. P and S large, well marked. Repeat 8h 20·6m.

(*d*) Beginning of disturbance lost, attending instrument.

(*e*) Quake felt south of Graham Island (Q.C.I.) wireless operator reported.

(*f*) Quake and tidal wave reported from the Samoa Islands.

(*g*) Repeat 4h 54·5m. A quake of great intensity reported from Chili.

VICTORIA, B. C.

F. N. DENISON, SUPERINTENDENT.

No.	Date 1917	P.T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks
		h m s	h m s	h m s	h m s	h m s	mm	
1736	June 3	19 41 35		19 44 04	19 46 20	19 50 23	0·4	
1737	" 4	1 32 52	1 35 39	1 38 46	1 42 42	2 00 55	2·0	1,610 km.
1738	" 4	8 10 45			8 12 43	8 15 40	0·1	
1739	" 6			4 44 17	4 46 11	5 07 00	0·2	
1740	" 6	16 22 11?		16 37 23			0·05	First phase may be S.
1741	" 7	2 55 25?	2 57 24	2 59 52	3 00 52	3 05 50	0·2	1,100 km.
1742	" 8	1 04 16	1 10 4	1 14 36	1 19 31	3 53 54	14·0	(*a*) 4,020 km.
1743	" 9	17 41 31		17 44 59	17 47 28	18 04 49	0·2	
1744	" 10	4 33 34		4 34 34	4 35 33	4 55 23	3·0	550 km.
1745	" 10			6 04 18	6 08 16	6 13 44	0·2	Probably part of Italian quake.
1746	" 13	7 05 12	7 13 09	7 20 05	7 31 59	10 00 14	2 0	Repeat L. 9h 40m 5s. 6380 km.
1747	" 16			15 50 30	15 52 28	15 57 24	0 05	
1748	" 22	5 39 43		5 40 42	5 42 11	5 45 40	0·2	
1749	" 24	20 11 23				20 58 59		L. and Max. lost at cut off.
1750	" 26	6 01 56	6 10 51	6 25 14	6 30 41	10 22 45	19	(*b*) 7,510 km.
1751	" 27	12 56 26			13 01 24	13 09 50	0·2	
1752	" 28	14 34 08			14 37 06	14 42 33	0·2	
1753	" 29	16 23 30			16 26 57	16 33 37	0·1	
1754	" 30	18 21 46			18 30 41	18 40 37	0·1	
1755	July 1	13 21 18		13 22 07	13 23 06	13 32 26	0·6	(*c*) L. may be S. waves.
1756	" 4	0 50 42	1 01 02	1 18 15	1 41 51	2 28 05	0·5	9,190 km.
1757	" 4			6 29 04	6 40 22		0·2	
1758	" 9	0 47 58		0 50 27	0 51 27	0 54 55	0·2	
1759	" 11	23 14 54		23 17 23	23 22 20	23 34 14	0·3	
1760	" 12	12 06 57	12 12 51	12 23 10	12 31 47	12 59 34	0·6	4,120 km.
1761	" 12			13 27 06	13 30 03	13 37 55	0·2	
1762	" 15	11 37 52?		11 44 18?	11 48 20	12 14 37	0·3	
1763	" 25	3 25 50	3 28 47	3 30 45	3 32 43	4 32 43	1·5	1,710 km.
1764	" 25	22 42 33		22 45 00	22 46 58	22 51 53	0·2	1,400 km.
1765	" 27				3 44 56	5 36 17	3·5	Clock stopped, 1st phases miss'd
1766	" 27		16 42 48?	16 48 30	16 54 06	17 08 42	0·1	
	" 28	Earthquakes missed when clock stopped.						
1767	" 29	14 51 27	14 58 49	15 05 43	15 10 53	16 17 31	0·4	5,730 km.
1768	" 29	22 06 43?	22 15 34	22 35 14	22 50 58	1 16 33	3·5	(*d*) 7,420 km. ?
1769	" 30				17 21 29		0 05	Thickening.
1770	" 31	0 36 14?	0 45 05	0 50 00	0 58 51	1 40 10	0·6	7,420 km.
1771	" 31	3 33 47		3 40 09	4 22 28	4 39 41	0·2	P. phase may be S.

Boom period 18 seconds. Pillar inclination 1mm. = 0″·54

(*a*) San Salvador destroyed. Repeat 3h 26m 10s and 3h 29m 10s.

(*b*) Repeat 9h 35m 58s; 9h 42m 16s; 9h 46m 16s; 9h 52m 58s.

(*c*) This quake felt at south end of Graham Isl. (Q.C.I.). Wireless operator reported this as a sharp quake at 5h 20m, 120th mer.

(*d*) Repeat 0h 25m 24s with amplitude of 1·5 mm.

Vertical Seismograph

Date 1917	P.T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks
	h m s	h m s	h m s	h m s	h m s	μ	
June 4	1 32 52	?	1 38 52	1 39 52		8*	
" 8	1 04 16	1 11 04	1 19 06	1 30 28	?	25*	5100 km.
" 10	4 33 34		4 34 20	4 38 02	4 48 00	33*	550 km.
" 13	7 05 12	?	7 20 30	7 38 42	?	7*	
" 16			15 50 30	15 52 30		3*	1120 km. L.W. may
" 26	6 02 00	6 11 30	6 25 06	6 27 21	?	83*	8200 km. [be P.T.
July 1	13 21 37		13 22 37	13 22 55	13 27 55	1*	
" 25	3 25 30	3 29 00	3 31 42	3 32 30	3 48 00	10*	2080 km.
" 27	1 10 28	1 20 48	1 29 42	1 36 18	2 16 00	8*	(*a*) 9000 km.
" 27			3 36 00	3 41 00	?	10*	
" 29	22 04 24	22 17 00	22 35 06	22 45 00	?	16*	12400 km.

*True earth movement.

(*a*) Milne clock stopped, so Milne record to correspond was lost.

J. Y.

ASTRONOMICAL NOTES

ASTROPHYSICS.— The astronomer is at a disadvantage as compared with the chemist or physicist. He is powerless to vary the conditions which determine the character of what he observes; he cannot cause the repetition of any single phenomenon for a more leisurely study of its details, nor does he know what would have occurred had the conditions been differently ordered. Often he can only wait for time to shift changing configurations slowly into view, as the varying positions of the planets. Sometimes, in the slow transformations of an evolutionary process, he can bridge endless intervals of time and picture the changing details by studying, among the individuals affected, those which simultaneously find themselves in different stages of development. But frequently, without further clew, he can make no progress at all. The phenomena are so complex and their causes so obscure, that he is at a loss as to how to proceed. Especially is this true of occurrences in the atmosphere of the sun or a star, where he finds in operation powerful and little understood hydrodynamical forces, the intricate and confusing effects of fluctuating pressure and temperature, the complicating influences of powerful magnetic fields, and, perhaps, also those of extreme electrostatic conditions. From this maze there seems but one means of escape: to enter the physical laboratory and, by empirical methods, discover conditions which reproduce the phenomena viewed at the telescope. Astronomy to some extent can thus be made an experimental science, and the astrophysicist becomes a physicist whose laboratory includes the heavens as well as the earth.

Simple illustrations make clearer the principle involved. Simplest of all is the identification of terrestrial elements in the spectra of the sun and the stars. This, of course, could not have been done at all without parallel investigation in the laboratory; but the result is so familiar, and usually receives such emphasis as an astronomical achievement, that we forget the indispensable link in the evidence supplied by the physicist. — FREDERICK H. SEARES, *Publications Astronomical Society of the Pacific*, No. 170, (August, 1917).

SUMMARY OF CONCLUSIONS OF A PAPER ON "RADIATIVE EQUILIBRIUM OF THE STARS." — 1. If the mass-co-efficient of absorption is the same for all stars, the effective temperature varies as the sixth-root of the density, and the total radiation is independent of the stage of evolution, so long as the star is in a perfect gaseous condition. Conversely, the approximate confirmation of these laws by observation seems to show that the absorption is nearly the same for all stars.

2. Owing to the compensatory effect of radiation-pressure the distribution of temperature in the interior depends only to a very small degree on the molecular weight of the material or the amount of ionisation. For a giant star of type *G* the central temperature is of the order 5,000,000°.

3. Assuming the highest possible degree of ionisation in the interior, the mass-co-efficient of absorption is 5·4 C.G.S. units. If the co efficient depends on the temperature, this value refers to approximately the highest temperature in the interior. The absorption cannot anywhere exceed 30 C.G.S. units, except possibly for a very limited range of temperature.

4. The actual masses of stars correspond to the range in which radiation-pressure increases from trifling to predominant influence. Assuming that a gas-sphere in which gravitation is largely counter-balanced by radiation-pressure would be in a state approaching instability, and would readily break up under small rotational velocity or other causes, it is evident that the

matter of the universe must aggregate into bodies of mass agreeing quantitatively with the observed masses of stars.

5. With low ionisation the total radiation of a giant star varies approximately as the mass, with high ionisation as the square of the mass. In either case the observed range of luminosity of the giants indicates a very close uniformity of mass of the majority of the stars.

6. Determinations of the temperatures of stars too dense to behave as a perfect gas involve more doubtful assumptions. Assuming a high degree of ionisation, a theoretical model has been found which appears to represent the chief results of observation satisfactorily. According to this, a body must have at least one-seventh the sun's mass in order to attain an effective temperature of 3000° ; stars with mass less than 2·2 times the sun's mass will not reach the *B* stage. The maximum temperature is attained when the mean density is between 0·2 and 0·5. The distribution of the luminosities of the *B* stars may be expected to be strongly asymmetrical, the maximum frequency corresponding to minimum luminosity.

7. If contraction is the only source of energy, the giant stage of a star's existence can scarcely exceed 100,000 years — PROFESSOR A. S. EDDINGTON, *Monthly Notices R. A. S.*, No. 8, (June, 1917).

TIME ZONES AT SEA.— There are several matters of time-reform in the air (or on the carpet, as the French say), one of which, at least, will probably be realised in the not distant future, for the scheme is already well advanced. This is a proposal to extend the hourly zone-time system, generally used on land, to the ocean, and the suggestion is that time should be kept according to this system both on the vessels of the Navy and of the mercantile marine. The scheme originated with our French allies, who have decided to adopt it in their Navy, and it has been discussed at an official conference in England by representatives of many important interests, M. Renaud, Director of the French Hydrographic Service, being present. The actual pro-

ceedings at this conference have not been made public yet, but there can be no impropriety in giving the substance of a note which appeared in the *Comptes Rendus* of the Paris Academy for July 23.

On board ship there are time-keepers of two kinds. There are chronometers for the purpose of navigation, which naturally show Greenwich time, and there are the clocks in use for the everyday life of the ship, which are set day by day, more or less at the discretion of the captain, but, speaking generally, show the local time of the place where the ship happens to be. It is this latter class of instruments to which the reform is to apply. It is proposed that the clocks on board ship shall always show a time which differs an integral number of hours from Greenwich time. The clocks need not be altered immediately on entering a new time-zone ; but this will be left, as before, to be controlled by circumstances. These clocks, however, will always show the time of some hour-zone — preferably that in which the ship then is, and the number of the zone that the clock is then keeping is to be exhibited beside the clock ; and in any entry of time made from the clock, in the ship's log or elsewhere, the number of the zone is to be entered. The numeration of the zones was discussed at the conference, and it has been decided that they should be + 1, + 2, + 3 . . . West from Greenwich, − 1, − 2, − 3 . . . Eastward. All this may seem rather unimportant, but the result of the change will be that Greenwich time can be deduced from the clock time quite easily ; and it has been decided that in the case of wireless messages the time of sending shall always be given in Greenwich time, which illustrates the purpose of the new scheme. *Summer Time* is to be ignored entirely.

The other reforms referred to above emanate from this. It is proposed in the first place that the astronomical day shall be made to agree with the civil day ; or, in other words, that in the National Ephemerides the day shall begin at midnight, which is to be 0 hours, and the hours are to be numbered from 0 to 23. The alteration of the Astronomical day is a very debatable matter, and the Astronomer Royal and Professor Turner are the

joint signatories of a letter in the *Observatory Magazine* of this month, which asks for the opinion of astronomers on the point. More than twenty years ago this same question was under discussion, but nothing materialised. The cognate question of numbering the hours of the civil day from 0 to 23, which was also discussed at the earlier date, will probably again arise. There is also talk of reviving in England the old Board of Longitude, which came to an end in 1828.—H. P. HOLLIS, *English Mechanic and World of Science*, August 17, 1917.

HARVARD COLLEGE OBSERVATORY.—*Bulletin*, No. 641.—A telegram from Professor W. S. Adams, of the Mount Wilson Observatory, states that a Nova has been discovered by Mr. G. W. Ritchey in the outer portion of the spiral nebula N.G.C. 6946, 105″ south and 37″ west of the nucleus. The magnitude was estimated as fourteenth on a photograph taken July 19, 1917. An early photograph shows no star as bright as the twentieth magnitude in this position.

This nebula is H. IV. 76 Cephei. Its approximate position for 1900 is R.A. = $20^h\ 32^m{\cdot}4$, Dec. = + 50° 44′. An excellent photograph of this object is given in the publications of the Lick Observatory, Volume VIII., Plate 62, on a scale of 10″ = 1 mm.

A photograph taken with the 16-inch Metcalf Telescope on June 25, 1917, shows stars of the fifteenth magnitude, but the Nova is not visible.

The last new star discovered previous to this is Nova Geminorum, No. 2, found by Enebo on March 12, 1912.

Bulletin, No. 642.—A letter from Dr. Heber D. Curtis, of the Lick Observatory, states that he has found two new stars in the spiral nebula N.G.C. 4321, Messier 100. The position of this nebula for 1900 is R.A. = $12^h\ 17^m{\cdot}9$, Dec. = + 16° 23′. The first nova appeared at some time prior to March 17, 1901, and was then about 13·5 magnitude. It was a magnitude fainter in April, and has now completely disappeared. It was 110″ west and 4″ north of the nucleus.

The second nova appeared at some time before March 2, 1914, and was then about 14 magnitude. It was 24″ east, and 111″ south, of the nucleus.

These objects do not appear on Harvard plates of this region taken on June 30, 1896; January 16, 1901; February 22, 1912; March 13, 1912; and February 10, 1913, which show stars of the magnitudes 15·5, 14·5, 16·2 15·5, and 15·2, respectively.

A letter just received from Professor Adams states that Ritchey's nova is growing rapidly fainter. On July 27 it was from one to two magnitudes fainter than on July 19. Its color index shows that it cannot be a long period variable.

The variable star *R* Coronæ, 154428, reached a maximum, 9·2 magnitude, on July 27, 1917, and is now growing fainter. On August 8, it was 10·5 magnitude.— EDWARD C. PICKERING.

NINTH SATELLITE OF JUPITER.— The preliminary orbit derived from observations in 1914 at the time of discovery has been corrected by observations made during the re-discovery at Lick during the 1915 opposition, and this enabled the observers to locate it more easily at Mount Wilson during the recent opposition in 1916. Four images have been found on plates taken by Shapley with the 60-inch reflector, and the orbit is being corrected by means of the collected observations of all three oppositions, the main results being shown in a diagram of the orbits of the eighth and ninth satellites. On account of their great distance from the primary the perturbations produced by the sun are very large for both satellites, and the orbits are not even approximate ellipses. The mean period of the ninth satellite is about 745 days, while the eccentricity appears to be a little less than that of the eighth satellite. The magnitude at mean opposition is estimated at 18·6, which with reasonable assumption for albedo and color index would indicate a diameter of about 15 miles. [See *Abstract 416*, 997, (1915)].—S. B. NICHOLSON, (National Academy of Science, *Proceedings* 3, pp. 147-149, March, 1917).

J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

FINE AURORAL DISPLAYS

The last few weeks have been remarkable for the number and beauty of the auroral displays, still further impressing the fact of their relation to sun-spot activity. Some of the displays were seen over wide areas and were accompanied by great disturbance of the earth's magnetism, while others have exhibited very striking forms.

Mr. A. F. Hunter sends the following note :—

On two moonless nights (July 21 and 22) at Barrie, I observed auroras of some interest, and I send the following particulars for comparison with the observations made in other places on the same dates. Soon after sunset on July 21st, signs of an aurora became visible, *viz.*, at 8 p.m. when darkness set in, there was a high cirrus glow in the west where the sun went down. After nine, a faint auroral light appeared in the northeast, and by 10.15 p.m. this glow formed a low arch, and soon afterward streamers appeared. By 10.30 p.m. there was a good display of streamers throughout the northern sky, and at the same time rose tints in the sky became quite abundant and in a few places strong. By 11 p.m. the display had begun to diminish. Distant lightning flashes were visible during the auroral display. On the night following (*viz.*, July 22) there was another display, less in magnitude and duration but with some interesting features. From 8 p.m. onward, there was evidence of cirrus haze from the glow in the west. About 9 p.m. an auroral arch was to be seen overhead coming from a little southward of the sun's position, *i. e.*, from where the sun had been a

short time before. This arch moved southward to the zodiac where it slowly faded away.

During the evening of August 8 and the morning of August 9 occurred a very wide-spread display. Writing from Viking, Alberta, Mr. H. B. Collier sends the following clipping from the Edmonton *Bulletin* of August 9:

> There was a remarkable auroral display last night which lasted for several hours. The streamers from the north covered the entire expanse of the heavens until the half moon was fairly paled in the shimmering green and pinkish light. The exhibition culminated about half past eleven o'clock in a burst of light in the very zenith, which resembled nothing more than a gigantic shell explosion. The brilliancy radiated in every direction, attracting much attention by reason of its striking intensity and beauty. Shortly afterward the display faded away.

Commenting on this description, Mr. Collier in addition mentions a streamer of some 8° in width at 10 p.m. which extended from the horizon to the first star in the handle of the "Dipper," (Delta Ursæ Majoris). This was of glowing red whereas the remainder of the display was pale green and white. The intensity of the red and its persistence in this streamer were worthy of mention.

This display was felt over a great area, as the following Canadian Press despatch, dated Chicago, August 9, shows:

> The Aurora Borealis, or northern lights, interrupted wire communication over the northern half of the United States and all Canada from the Rocky Mountains to the Atlantic Ocean, and even was felt in southern latitudes last night and for several hours early to-day.
>
> The phenomenon became visible and began to affect telegraph and telephone wires shortly before midnight last night, and for several hours before daylight this morning many trunk line circuits were useless most of the time.
>
> The display of the aurora in Colorado was described as particularly bright, many persons believing the blood-red appearance of the northern sky was caused by forest fires. A despatch from Denver quoted Professor Howe, of the Department of Astronomy of Denver University, as saying such a display had never been observed before in Colorado, to his knowledge.
>
> Telegraph officials said the disturbance was more widespread than for many years, the phenomenon usually being confined to northern latitudes.

A friend of the present writer, who at the time was a navy wireless operator on Sable Island, reports a great auroral display

there at about 3 a.m., August 9. Probably the magnetic effects will show that it was felt over most of the earth.

In August some strange displays have been seen by the writer at Go-Home Bay, Ont. (Lat. 45° N., Long. 79° 56′·6 W.). On the 20th, at 10 p.m., two remarkable streamers were seen spanning the sky. One rose from the horizon a few degrees north of the east point and the other from a few degrees north of the west point, they bent slightly to the north and came together some eight or ten degrees north of the zenith. Some of the observers compared them to great search-light beams, but to the writer they appeared more like some photographs of comets in which there are knots and irregularities in the tail — not straight and smooth as in a search-light. They remained steady for a considerable time — at least half an hour. Readers of these pages will remember that something very like this was seen by Professor John Satterly (on August 28, 1916, I think) at Jackson's Point, which he described in "Notes and Queries."

On the following evening there was a much more extended display, almost the entire sky being filled with the exception of a portion in the south extending to about 30° above the horizon. There were numerous streamers continually shooting upwards and 'clouds' of different sizes also in rapid motion towards the zenith. The whole was very similar to that seen on August 26, last year, (which has been described fully in the JOURNAL), but the sky was not quite so well covered this time. An attempt was made to locate the focus of the streamers; at 9.57 (Eastern Time) it was estimated to be at Beta Cygni. Facilities are not at hand to calculate how close this is to the magnetic zenith, but the computation will be made later.

NO DAYLIGHT SAVING IN CANADA

A short time ago Sir George Foster, Minister of Trade and Commerce, brought down in the Canadian House of Commons a measure having for its object the introduction of daylight saving next summer. Its reception was very unfavorable. Ridicule of all sorts was hurled at the proposal, scarcely a member daring to do it reverence, and the bill was withdrawn. An outsider would almost have thought that Canadians were a chosen people,

peculiarly devoted to improving each shining hour, and hence not needing any crude act of parliament to assist them to use their time to better advantage.

But, as so often is the case, it is quite possible that the minute minority which supported the bill was in the right after all. When this daylight saving project was first suggested the present writer was decidedly opposed to it. It seemed unscientific, almost childish, and entirely ridiculous to propose to make one rise earlier by act of parliament. But various European countries, considered more conservative than the enlightened northern half of America, boldly put it in force. Declaring it to be good after one season's trial, they have continued it for another. Apparently it has proved a real success. Why would it not in Canada? Moreover, if the scheme comes into operation in the United States next summer it will be a distinct disadvantage to have our time different from theirs.

There is a general feeling that our legislators do not afford a very good example of saving time either during daylight or darkness.

ARE THE NEBULÆ SEPARATE UNIVERSES?

During recent years much energy has been expended upon investigations of the nebulæ, and in the present number is a very able discussion by Director Campbell, of the Lick Observatory, of some problems relating to these fascinating objects. As is well-known, it has been thought that these bodies, especially the spirals, are far distant universes, that, for instance, the Great Andromeda Nebula, though occupying a small area of the sky, is in reality similar to our Milky Way. This view has been somewhat strengthened by the measurements of its proper motion published in the *Astronomical Journal*, for June 29, 1917, by Barnard, who finds that there has been little or no displacement during the past eighty years. Now Slipher and others have found that this nebula is approaching us with the huge velocity of 330 kilometres per second. From this we conclude that either the motion must be practically in the line of sight or the nebula must be at an exceedingly great distance. The latter is the more probable.

C. A. C.

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